Underwater Behavior of Blue Whales Examined with Suction-cup Attached Tags

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LONG-TERM GOALS

The overall long-term goal of the research is to examine the underwater behavior of blue whales, especially vocal and feeding behavior. Understanding whale vocal behavior is important to both evaluate potential impacts of underwater sounds and also to allow interpretation of remotely gathered data on whales calls from Navy hydrophone arrays or remote recording packages (*e.g.* Oleson *et al*. 2003). While increasing attention has been paid to the remote monitoring of blue whale behavior and vocalizations, relatively little is known about the behavior of individual animals (McDonald *et al.* 2001). We seek to monitor a variety of parameters including visual behavior, vocalizations, and dive patterns in the context of individually identified known-sex animals.

OBJECTIVES

The project has the following objectives:
1. Obtain integrated visual, acoustic, dive and feeding behavior of blue whales.
2. Examine relationship of dive and acoustic behavior with sex, size, sighting history.
3. Examine differences in behavior among different habitats and seasons.
4. Promote collaboration and sharing among groups working on visual/acoustic tags on whales.

APPROACH

Tagging in 2002 consisted of deployment of three instrument packages on blue and humpback whales. All three were attached to the whale with a suction-cup and deployment was achieved by close approach and placement on the whale using a long pole to make direct contact with the whale. The three deployed tags were:
1. *Crittercam:* Package developed by National Geographic and termed "Crittercam", onto blue whales (Marshall 1998, Williams *et al*. 2000, Francis *et al*. 2001). The instrument packages deployed contained a combination of the following instruments and devices:
    - Underwater video camera to record behavior and prey
    - Hydrophone and recording system for underwater vocalizations
    - Pressure sensor to record water depth
    - Sensor to monitor and record water temperature
    - VHF tag to provide local positioning information
2. *Burgess Bioacoustic Probe:* An acoustic tag developed by Bill Burgess of Greeneridge Scientific Services with support from ONR (Burgess *et al*. 2003) and deployed as part of a collaboration with

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Scripps Institute of Oceanography (John Hildebrand and Erin Oleson). Joe Olson of Cetacean Research helped to test the tag and develop a delivery and attachment method for the tag. The tag recorded underwater sound and dive depth. The tag was potted in resin and was much smaller than in previous tag deployments. The tag sampled acoustics with 16-bit resolution at bandwidths up to 14 kHz, as well as temperature and depth with 12-bit resolution. Constant acoustic sampling at 2 kHz fills the 576-MB solid-state flash disk in 41 hours. Low-power three-volt electronics allow a single half-AA-cell lithium battery to power the entire tag.

3. *WHOI (Woods Hole Oceanographic Institute) digital tag*: The WHOI digital tag has been developed in recent years and successfully tested on a number of species (Johnson *et al*. 2003). A graduate student at WHOI, Becky Woodward, collaborated with us in conducting deployments in the Santa Barbara Channel. The digital tag consists of:
    - a hydrophone (acoustic) channel with a 12-bit analog-to-digital converter, and a programmable gain filter. The typical acoustic sampling rates are 16kHz or 32 kHz.
    - a pressure sensor to measure depth, 0-2000m, resolution of 0.5m.
    - a thermistor both for water temperature and to correct the pressure sensor readings.
    - 3-axis accelerometers to measure pitch and roll.
    - 3-axis solid-state magnetometers to measure heading.
    - a salt water switch to detect surfacings and to trigger the initial recording of data.
    - a nichrome wire release mechanism, which can be triggered to corrode away slowly and release the tag from the animal after a set amount of time.
    - a VHF radio beacon to enable tracking and focal observations of the whale when it surfaces, and to find the tag for recovery when the suction cups release from the animal.

Field monitoring in addition to attachment of tags included photographic identification of individual animals to link with sighting histories from archived data (Calambokidis *et al.* 1990), collection of skin from biopsy or sloughed skin to allow sex determination, and photogrammetry to estimate size (Calambokidis *et al*. 2001).

Figure 1. Burgess bioacoustic probe on the back of a blue whale off San Diego, 30 June 2002.

WORK COMPLETED

We had success deploying all three types of tags (Crittercam, Burgess Bioacoustic probe, and WHOI dTag) on blue whales in 2002. In 46 approaches of blue whales in 2002, we were able to successfully

attach a tag in 25 occasions. In all cases in 2002, we were able to successfully recover the tag, however, in two cases, the tag was not functioning. Our successful attachment rate in 2002 was much higher rate than in past years and reflects a steadily increasing success rate since we started (Table 1).

Table 1. Success rate in approaching blue whales to deploy suction-cup attached tags.

	Approach	Contact		Attach		Recover/working	
		#	%	#	%	#	%
Blue whales							
Bodega 1999	>15	7	<50%	1	<10%	1	<10%
Monterey 2000	6	3	50%	1	17%	1	17%
Baja 2001	16	7	44%	5	31%	4	25%
S California 2001	26	18	69%	12	46%	11	42%
S and C California 2002	46	27	59%	25	54%	23	50%
Total	109	62	57%	44	40%	40	37%

The 44 deployments off all three types of tags on blue whales completed through 2002 have been in a variety of locations and habitats (Table 2). Deployments in 2002 included:

1. Deployments of the WHOI dTag and Bioacoustic Probe on blue and humpback whales in the Santa Barbara Channel on 19-27 June including deployments in conjunction with a seismic-reflection survey by USGS and collaborative work as part of an SIO survey.
2. Deployments of the Bioacoustic Probe off San Diego on 30 June as past of surveys by SIO.
3. Deployments of Crittercam and the Bioacoustics Probe on blue whales in Monterey Bay on 16-20 September.
4. Deployments of Crittercam and the Bioacoustics Probe on blue whales then the Santa Barbara Channel 21-24 September.

Table 2. Locations, types of tags and years tags were successfully deployed on blue whales.

Region	Crittercam				Burgess	dTag	All
	1999	2000	2001	2002	2002	2002	
Cordell Bank	1						1
Monterey Bay		1		7	1		9
Santa Barbara Channel				6	7	2	15
W San Miguel			7				7
San Nicolas Is.			5				5
Off San Diego					2		2
Sea of Cortez, MX			5				5
Total	1	1	17	13	10	2	44

Our longest deployment to date was made with the Burgess Bio-acoustic Probe attached to the trailing animal of a pair of San Diego on 30 June 2002 (part of our collaboration with SIO). Biopsy samples revealed that the lead animal was a pregnant female and the tagged trail animal was a male. The tag stayed on somewhere between 25 and 39 hours. The 15 hours of data obtained before the memory filled up provided insights into diving and vocal behavior. Dive record for the tagged animal showed a dramatic shift in diving behavior over time going from: 1) spiked dives while traveling to 2) saw-tooth dives as it shifted to feeding in one area, then 3) progressively shallower feeding dives with the advent of darkness and the vertical migration of krill, 4) a resting mode at night with frequent shallow dives as

the animal milled slowly near the surface, and 5) a return to saw-tooth feeding dives that become progressively deeper with the onset of daylight.

While we had not initially identified this tagged animal as a calling whale, the tag data revealed it was producing intermittent calls throughout the night. These calls were of a consistent intensity and were produced, in some cases, when the lead whale was surfacing, indicating the tagged whale was producing the calls. Calls were produced at a very consistent shallow depth (12-25 meters) even though the whale was sometimes diving to close to 200 m in other portions of the dive.

Loud calls were also heard on deployments of one of the Crittercams and dTags in 2002. Calls were heard on the dTag on the trailing animal of a traveling pair in the Santa Barbara Channel. They were also heard on one Crittercam on the trailing animal of a group of three whales in the Santa Barbara Channel. The tagged animal slowed to a low speed and a second animal is seen next to the tagged animal during the period of the call.

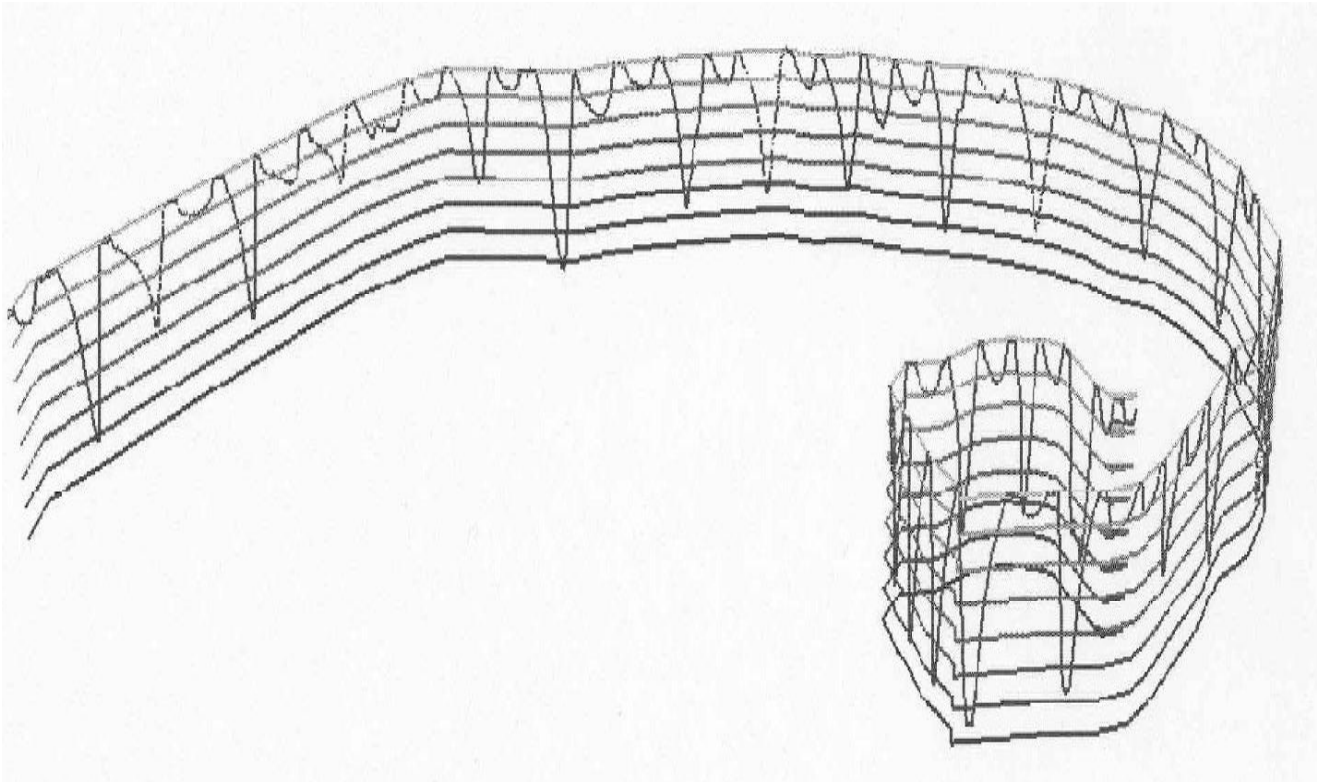

Figure 3. Dive and movement record from WHOI dTag based on tag data and tracking from boat on 24 June 2002 in the Santa Barbara Channel.

RESULTS

Results to date have provided valuable new information on both the feeding and vocal behavior of blue whales (Calambokidis *et al*. 2003). Key findings on the feeding behavior of blue whales include:

- Blue whales dive to a wide variety of depths some deeper than suspected (300m)
- Whales often approach prey from underneath, inverting to open the lower jaw into a prey field
- Confirmation that series of upward lunges are into prey
- Dramatic diurnal patterns in diving behavior and apparent shallow resting at night

- Pairs of whales are not engaging in cooperative feeding
- Blue whales, like other deep diving animals, largely glide when they are diving deep making use of negative buoyancy created by compression of air spaces (Williams *et al*. 2000)

Key findings on the vocal behavior of blue whales from both the tag data as well as collaborative research with Scripps Institute of Oceanography (Oleson *et al*. 2003) include:

- Most blue whales were not producing long patterned calls especially during feeding
- Even though much of the remote acoustic data describes and documents regular callers, irregular call behavior may be a more common behavior even though it is under-represented in the acoustic records
- Only males have been documented so far producing long calls
- There appear to be differences in social/behavioral contexts of non-callers, irregular and regular callers
- These findings complicate the goal of determining the relationship between acoustic detections and whale density

IMPACT/APPLICATIONS

Methods of approach and attachment that we have developed will be useful in attaching other instrument packages. Dive records of different blue whales will reveal the range of dive depths and behaviors they use in a variety of habitats. Visual records of blue whales will show some of the strategies they use in swimming and approaching prey. Acoustic records will contribute to an estimate of the proportion of blue whales vocalizing and the relationship of vocal activity to behavior, water depth, and sex of individuals.

TRANSITIONS

The expertise that we have developed in approaching and attaching tags to blue whales is being used in our collaborative research with both Scripps Institution of Oceanography and Bill Burgess of Greeneridge Sciences attaching acoustic tags to blue whales. We are collaborating with Moss Landing Marine Labs, University of California Santa Cruz, Tom Norris of SAIC, Nick Gales, and the Tagging of Pacific Pelagics Project during 2003. This will include a coordinated effort in September 2003 to deploy multiple tag types on blue and humpback whales in coordination with hydroacoustic surveys. We will be using our expertise in approaching and tagging blue and humpback whales to assist in deployments of satellite tags (Nick Gales), Manta tags (Tom Norris), as well as Crittercams and Bioacoustic Probes.

RELATED PROJECTS

We will continue collaborating with Scripps Institution of Oceanography and Mark McDonald in efforts to calibrate the acoustical behavior of blue whales. We will continue our work with National Geographic on further improvements to the Crittercams. Our photographic identifications of blue whales conducted on this project are being incorporated into the longer-term study of blue whale abundance and movements being conducted with Southwest Fisheries Science Center (Calambokidis and Barlow In Press, Calambokidis and Steiger 1997).

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